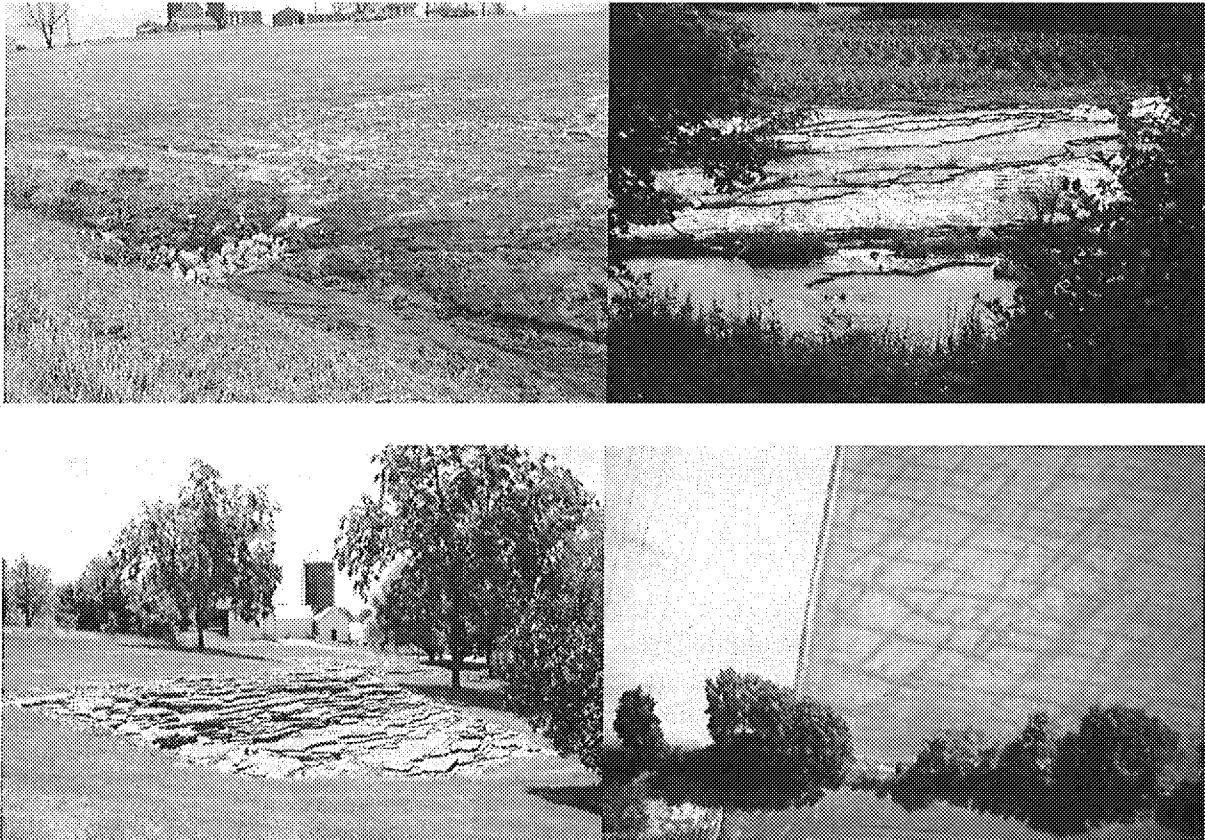


G3836

Final Report of the Northeast Wisconsin Karst Task Force



February 9, 2007

Edited By: Kevin Erb and Ron Stieglitz

Northeast Wisconsin Karst Task Force
Final Report
Table of Contents

| | |
|--|----|
| Executive Summary..... | ii |
| Background..... | 1 |
| Task Force Membership..... | 3 |
| Goals/Guiding Assumptions of the Task Force..... | 4 |
| Task Force Recommendations..... | 5 |
| #1: Creation of a Carbonate Bedrock Management Zone | |
| #2: Unification of State Codes | |
| #3: Carbonate Aquifer Protection Strategies – Long Term | |
| #4: Carbonate Aquifer Protection Strategies – Field Implementation | |
| #5: Carbonate Aquifer Protection Strategies – Basic Recommendations | |
| #6: Carbonate Aquifer Protection Strategies – Enhanced Recommendations | |
| Non-Manure Wastes..... | 18 |
| Needed Research..... | 18 |
| References..... | 20 |
| Appendix 1: Documentation of Local County Contamination..... | 23 |
| Appendix 2: Comparison of State Codes..... | 30 |
| Appendix 3: Farmer Committee Brochure..... | 36 |
| Appendix 4: Manitowoc Field Assessment Worksheet..... | 38 |
| Appendix 5: Wisconsin Interagency Karst Reporting Form..... | 39 |
| Appendix 6: Morrison Mapping Project..... | 42 |
| Figures and Tables: | |
| Figure 1: Depth to Bedrock..... | 2 |
| Figure 2: Map of average detected nitrate levels..... | 2 |
| Figure 3: Map of bacterial contamination..... | 2 |
| Figure 4: Map of maximum detected nitrate levels..... | 2 |
| Figure 5: Map showing a closed depression and area of focused infiltration/recharge..... | 10 |
| Table 1: Level of protection recommended based on vulnerability ranking and site specific criteria..... | 7 |

Cover Photos: Field runoff (and manure) entering a sinkhole in a road ditch that the farmer has filled in with field stone. Shallow bedrock in a cornfield along a Bower Creek tributary (Brown County), showing how field runoff can enter not only surface water, but groundwater as well. Exposed bedrock near a farmstead in Brown County. Air photo showing fracture traces in an alfalfa field. Photos courtesy of WDNR, UW-Extension, John Luczaj (UW-Green Bay) and the Calumet County LCD.

As noted previously, there are significant differences in the setbacks and prohibitions found in state codes and federal standards (WI NRCS 590) for different land applications for manure, and even more variation when non-agricultural wastes are considered (see Appendix 2). The Task Force recommends that the responsible state agencies examine the scientific data, if any, behind these recommendations and work towards a more uniform set of protections (regulations). This will require legislative action.

Key to this recommendation is that the same parcel of land may be approved by DNR for whey application, but restricted by a county LCD/SWCD (under ATCP 50/NR 151/WI NRCS 590) for manure application. In cases where land is suitable and approved for multiple waste applications, a single individual or entity should be responsible for determining the rates allowed, taking into consideration both nutrient loading (from all sources) and hydrology. A list of sites approved by various agencies for non-manured wastes should be provided to the local LCD/SWCD on a regular basis.

These findings need to be worked into the existing framework of local, regional and county agencies, and changes to any rules or ordinances should rely on the technical advice of experts in the field. Agencies on all levels should work together to maximize aquifer protection and minimize contradictions in recommendations.

3: Carbonate Aquifer Protection Strategies – Long Term

Midway through the Task Force deliberations, the group formed two subcommittees—one to look at Best Management Practices and a second to define Karst Vulnerability. The subcommittees presented their reports in September, and a coordinating subcommittee was formed to combine the reports and presented them to the Task Force. Not every member of the task force agreed with the final recommendations as outlined in this particular section, however a strong majority felt they should be included.

The Task Force approved the final subcommittee report with the understanding that these steps would enhance aquifer protection in a perfect science-based world. These recommendations are what counties, state agencies and the legislature must work towards in the future. We strongly encourage individual farmers and landowners to implement them voluntarily.

Final Report of the Long Term Strategies Subcommittee
Approved at the November 12, 2006 Karst Task Force meeting

The working group was charged with combining recommendations presented by the Karst Vulnerability and Best Management subcommittees at the September 12, 2006 meeting of the Northeast Wisconsin Karst Technical Advisory Committee.

The ground rules followed were:

1. The BMPs and vulnerability ranking recommendations were to be merged to form one recommendation.
2. We consider only scientific data in making our recommendation and not politics, practicality or economics.
3. We could modify the original BMPs and vulnerability rankings in our recommendation.

The second ground rule was interpreted to include professional experience and knowledge of karst landscape systems in addition to scientific studies as a basis for making recommendations. The recommendations are made in the context of an “ideal world” in which we answer the following question based on our current understanding and knowledge of how karst landscape systems work: *What practices and restrictions should be implemented to protect the quality of groundwater resources in areas with shallow carbonate bedrock?* It is possible that in the future some of the specific recommendations may need to be more restrictive to protect groundwater while others could be made less restrictive as new information, knowledge and technology is acquired.

The recommendations are limited to practices and restrictions relative to agricultural land applications of nutrients and animal waste and animal waste management and storage. That is the subcommittee’s field of expertise and knowledge. Other land uses may impact groundwater, but there are more qualified people to develop recommendations for those uses.

The recommendations are primarily intended to minimize groundwater contamination from pathogens and “brown water” and secondarily intended to minimize groundwater contamination from nitrate.

The vulnerability subcommittee proposed the following vulnerability ranking for NE Wisconsin (Table 1). Levels of protection fall on an arbitrary scale, with level 1 requiring the most protection. Most of our recommendations are based on these categories.

Table 1: Level of protection recommended based on vulnerability ranking and site specific criteria. Criteria are site specific, and multiple criteria may occur in the same agricultural field.

| Level of protection required | Criteria | Relative vulnerability to contamination |
|------------------------------|---|---|
| 1* | Less than 5 feet (60 inches) to carbonate bedrock, <i>and/or</i> closed depressions or any drainage areas that contribute water to sinkholes/bedrock openings | Extreme |
| 2 | 5-15 feet to carbonate bedrock | High |
| 3 | >15-50 feet to carbonate bedrock | Significant |
| 4 | Greater than 50 feet to carbonate bedrock | Moderate |

* Level 1 requires the most protection.

LAND APPLICATIONS OF WASTE IN SHALLOW CARBONATE BEDROCK AREAS:

1. Frozen or snow-covered ground and saturated soils

There is a high probability of groundwater contamination when manure is applied to frozen or snow-covered ground or saturated soils in Criteria 1, 2 and 3 in Table 1.

RECOMMENDATIONS:

| Hazard | Limitation | Exception/comments |
|---------------------------------------|--|---------------------------|
| Frozen, snow-covered, saturated soils | No applications of manure in Criteria 1, 2, and 3 areas. | None |

2. Soil Depth Restrictions

There is a high probability of groundwater contamination when manure is applied to soils in Criteria 1.

RECOMMENDATIONS:

| # | Hazard | Limitation | Exception/comments |
|----------|--|--|---------------------------|
| 1 | Land with less than 3 feet of soil to bedrock | No applications of manure. | None |
| 2 | Soils 3 to 5 feet to bedrock | Maximum application rates should be 3,000 gal/acre per application (or solid waste ton/ac equivalent) with a maximum application rate of 6,000 gal/yr. | None |
| 3 | Soils 3 to 5 feet to bedrock | Shallow incorporation (<10 inches) of all wastes immediately after application. No deep injection of wastes. | None |
| 4 | Areas with >5 to 50 feet of soil to carbonate bedrock (Categories 2 and 3) | Incorporation of all wastes immediately after application. | None |

3. Setbacks and Land Draining to Sinkholes, Closed Depressions or Bedrock Openings (includes losing streams on carbonate bedrock)

- There is a high probability of groundwater contamination when manure is applied to land areas within closed depressions and within drainage areas that contribute runoff to sinkholes or bedrock openings (Criteria 1).
- Land areas near channels and concentrated flow paths that deliver runoff to closed depressions, sinkholes and bedrock openings are the most critical to the quality of runoff water.
- No runoff or concentrated flow of liquid wastes.

RECOMMENDATIONS:

| # | Hazard/Sensitive Feature | Limitation | Exceptions/comments |
|---|--|--|---------------------|
| 1 | Sinkholes, bedrock openings, surface inlets, and areas of focused infiltration within closed depressions | No applications of wastes within 100 feet. | None |
| 2 | Delivery system * to sinkholes, bedrock openings, surface inlets, and areas of focused infiltration within closed depressions. | No application of wastes within 100 feet. | None |
| 3 | Closed depressions, regardless of soil depth. | Incorporation of all wastes immediately after application. | None |

* Delivery system is a defined channel or concentrated flow path.

4. Requirements for Persons Who Plan or Conduct Applications of Animal Wastes in Shallow Carbonate Bedrock (<50 ft) Areas

RECOMMENDATIONS:

| Hazard/Sensitive Feature | Limitation | Exceptions/comments |
|---|---|---------------------|
| Areas with less than 50 feet of soil to carbonate bedrock (Categories 1, 2 and 3) | Require field investigations to identify and map closed depressions, sinkholes, bedrock openings, bedrock outcrops, surface inlets, and areas of focused infiltration within closed depressions and drainage areas to these features (Figure 5) during nutrient management planning | None |
| | Require a spill response plan for waste storage, transport, and applications. | None |
| | Require training on karst topography, spill response planning, and field identification of the above sensitive features. | None |

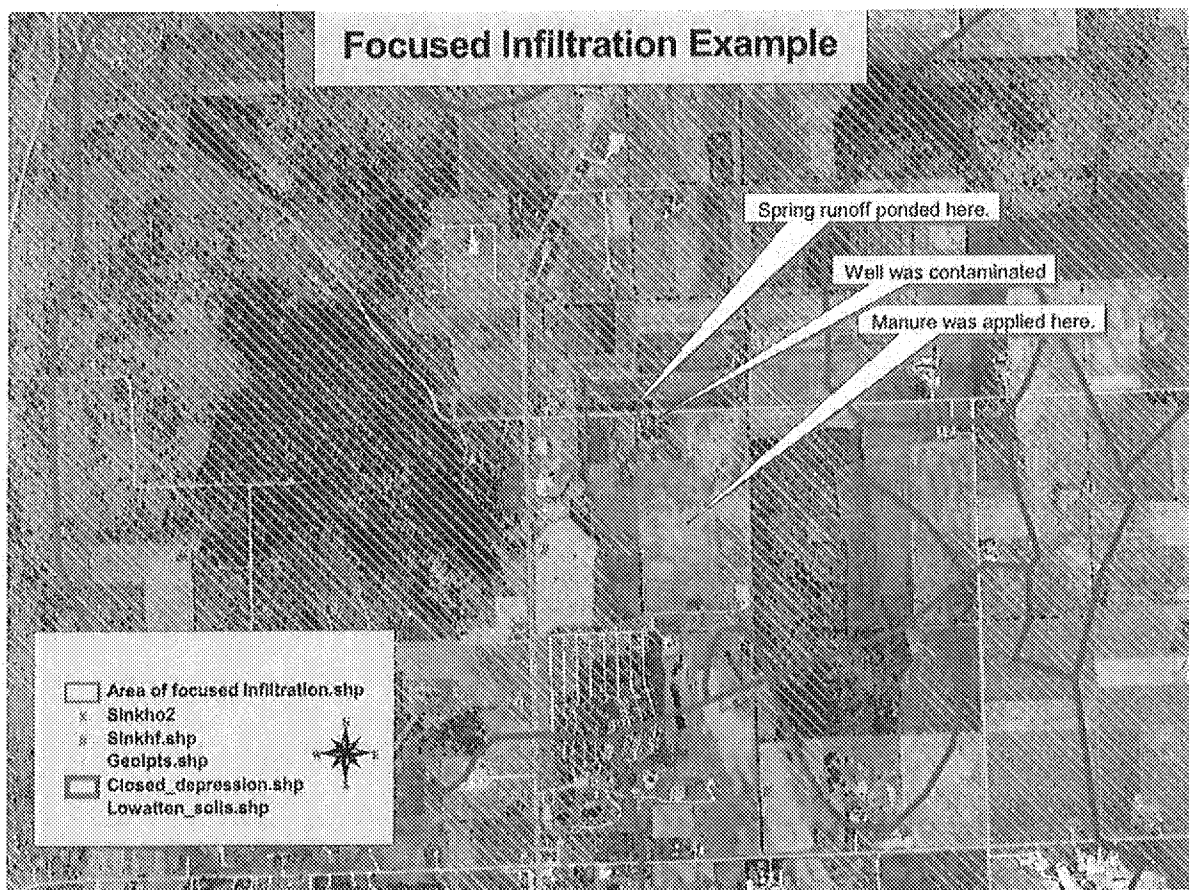


Figure 5: Map showing several closed depressions (outlined in Green) in Door County. During spring runoff, snowmelt (and field runoff) accumulates in the low area outlined in red (note no identified sinkhole in the low area). Within a few days of the ponding, manure was reported in a neighboring well. The field where manure was applied was not marked as restricted for manure application due to shallow soils, but the area where runoff ponded was restricted. The shaded area on the map (lowatten_soils.shp layer) are low attenuation soils or those mapped as high hazard (WI NRCS 590 Tech Note) where both winter spreading is prohibited and incorporation required. The delivery systems to the area of focused infiltration were determined by 2-foot contours, orthophoto imagery and a field inspection. This map is for example purposes and should not be used for actual regulation or management. Map courtesy Door County SWCD.

WASTE STORAGE AND POLLUTED RUNOFF FROM CONCENTRATED WASTE SOURCES IN SHALLOW CARBONATE BEDROCK AREAS:

1. Temporary, Unconfined Stacks of Manure and Derivatives

- a. Areas with Criteria 1 and 2 vulnerability rankings have extreme or high susceptibility to groundwater contamination and therefore would meet the definition of a Water Quality Management Area (WQMA) under NR151.
- b. NR 151 states: "A livestock operation shall have no unconfined manure pile in a water quality management area."
- c. Table 9 of USDA-NRCS Technical Standard 313, Animal Waste Storage Facility defines setback distances, waste consistency, stack size, stacking period and frequency, and conservation BMPs for unconfined manure pile sites.

RECOMMENDATIONS:

| # | Hazard/Sensitive Feature | Limitation | Exceptions/comments |
|---|--|---|---------------------|
| 1 | Soil less than 15 ft to bedrock (Criteria 1 & 2 areas) | No unconfined manure piles* | None |
| 2 | Sinkholes, bedrock openings, surface inlets, and areas of focused infiltration within closed depressions. | No unconfined manure piles within 1,000 feet. | None |
| 3 | Delivery system to sinkholes, bedrock openings, surface inlets, and areas of focused infiltration within closed depressions. | No unconfined manure piles within 1,000 feet. | None |
| 4 | >15-50 feet of soil | No delivery of runoff from unconfined manure piles to the hazards/sensitive area features in the above 3 rows. Unconfined manure piles in Criteria 3 areas must meet the most protective criteria set forth in Table 9, NRCS Technical Standard 313 (12/05) for 16 – 32 % solids waste consistency under the categories of size and stacking period, hydrologic soil groups, and surface separation distance. | None |

* As defined in NR 151, an unconfined manure pile is a quantity of manure that is at least 175 cubic feet in volume and that covers the ground surface to a depth of at least 2 inches and is not confined within a manure storage facility, livestock housing facility or barnyard runoff control facility or covered or contained in a manner that prevents storm water access and direct runoff to surface water or leaching of pollutants to groundwater.

2. Waste and Feed Storage Facilities

There is a significant risk of soil subsidence in areas with sinkholes, other karst features, and shallow soils over carbonate bedrock that could lead to groundwater contamination from waste or feed storage facilities.

RECOMMENDATIONS:

| # | Hazard/Sensitive Feature | Limitation | Exceptions/comments |
|---|---|--|---------------------|
| 1 | Areas with less than 50 feet of soil to carbonate bedrock (Categories 1, 2 & 3) | No earthen-lined manure impoundments in Criteria 1, 2 and 3 areas. | None |
| 2 | Areas with less than 50 feet of soil to carbonate bedrock (Categories 1, 2 & 3) | Waste storage facilities built before a certain date* are to be inspected and certified by a qualified person. If not certified they must be properly abandoned, upgraded, or inspected annually or when emptied for structural integrity by a qualified person. | None |
| | | Animal waste storage facility capacity of at least 9 months of waste generated. | None |
| 3 | Sinkholes, bedrock openings, surface inlets, and areas of focused infiltration within closed depressions in areas 50 feet or more of soil over carbonate bedrock (Criteria 4) | No manure or feed storage facilities within 400 ft. | None |

* Certain date: Decision left up to local jurisdiction

Outside Animal Lots

Direct infiltration and runoff from outside animal lots is a significant contributor to groundwater contamination in areas with sinkholes, other karst features and shallow soils.

RECOMMENDATIONS:

| Hazard/Sensitive Feature | Limitation | Exceptions/comments |
|--|---|--|
| Outside animal lots, feed lots, and milking facilities in areas with less than 15 feet of soil over carbonate bedrock (Categories 1 and 2) | No discharge of untreated waste from outside animal lots and feedlots or untreated milkhous wastewater. | Treatment is operationally defined (see below) |

The required BMPs to adequately treat waste generated from outside animal lots will be dependent on soil depth, number and type of animals, density of animals, etc. Appropriated treatment may range from low density/duration grazing to complete confinement and collection of waste and runoff from outside animal lots. Other examples of treatment BMPs include: wastewater treatment strips, diversions, heavy use area protection, roof runoff structures, prescribed grazing, etc.

KARST FEATURES (SINKHOLES, BEDROCK OPENINGS)

Dumping waste materials or directing polluted runoff and tile discharge water to these features will cause groundwater contamination.

RECOMMENDATIONS:

| Hazard/Sensitive Feature | Limitation | Exceptions/comments |
|--|---|----------------------------|
| Sinkholes and bedrock openings at the land surface | No dumping of waste materials into these features. | None |
| | No drain tile outlets in these features.* | None |
| | No diverting or directing of surface runoff to these features. | None |
| | Presume that waste material or polluted runoff entering these features is reaching groundwater and is a source of groundwater contamination (for regulation purposes).* | None |
| | Establish and maintain a permanent vegetative buffer around these features that is at least 100 feet wide. | None |

* Under current state law, tile drainage systems entering sinkholes are considered injection wells and therefore illegal.

The approved report included several additional recommendations, all of which have been included elsewhere in this document.

4: Carbonate Aquifer Protection Strategies – Field Implementation

A fourth subcommittee (Agricultural Field Implementation) formed independently during the Task Force deliberations. This group met with about two dozen farmers, crop consultants and professional manure applicators. Its goal was to develop a set of simple, easy to implement management practices for livestock and cash grain farmers that would reduce the risk of aquifer contamination. The subcommittee's report was presented and accepted at the November Task Force meeting.

The farmers and agricultural professionals who developed these steps strongly encourage farmers to voluntarily adapt the recommendations. For the purposes of this report, many of their recommendations have been included in the Basic Recommendations below, and are so noted with an asterisk (*). The full version of the report is found in Appendix 3.

5: Carbonate Aquifer Protection Strategies – Basic Recommendations

The members of the Taskforce considered an array of actions and management practices that can be implemented by farmers, professional service contractors, rural non-farm landowners, and county and town governments. A common element of these activities is that they have limited economic impact and require no action by a local body of government.

Most of the recommendations are not new concepts and many are already being applied and followed on a scattered basis throughout Northeastern Wisconsin. Significant progress can be made in groundwater protection with a wider and more consistent application of these practices and a greater appreciation of the value and effectiveness of these rather simple actions. Not all are totally without cost. Plugging a well has a direct out-of-pocket cost, while setbacks and buffer strips reduce crop acreage. However, over time, these steps will reduce the number of threats and incidents that require remediation. The key to progress is increased awareness of environmental and land use factors that affect groundwater in the region fostered by citizen education. The cost of inaction can also directly impact rural residents, as the need to drill a new well (because the current one is not compliant with existing code) can decrease the resale value of a rural residence (just like a home with an old, multi-layer roof). If a new well is needed, a portion of the cost is often passed along to the new owner in the form of an increased sale price, but only if the market allows.

We encourage farmers and rural landowners to immediately implement the recommendations outlined below.

- Identify and map areas of shallow bedrock and obvious karst interface features on a field-by-field basis. *
- Provide detailed information to manure haulers before and during application and provide the same information to subsequent owners and operators. *
- Inspect fields for soil cracks, and plan pre-tillage prior to surface applications.*
- Adjust manure and fertilizer application rates to crops requirements, soil tests, existing soil moisture conditions, and when possible, to weather forecasts. Avoid manure applications when conditions pose the greatest risk.*
- Split manure applications to reduce the risk of runoff and downward movement.*
- Time manure application to crop nitrogen uptake (for summer alfalfa, no more than 2 weeks prior to seeding).*
- Spread manure according to a nutrient management plan and/or winter manure spreading plan.

- Avoid mechanical manure applications within a 250 foot radius of a private residence water supply well and within 1,000 foot radius of a well that is part of a municipal or community water system or a non-transient, non-community well that serves a captive population (rural school). Nitrogen fertilizer applications with these same areas shall be limited to soil test recommendations and made in accordance with the Wisconsin NRCS 590 nutrient management standard.
- Designate a centralized authority in each county (LCD/SWCD) to receive copies of all karst information and begin the process of designating local Karst Landscape Units, with input from local stakeholders and technical specialists.
- Temporary manure storage sites should be reviewed by technical experts and based on the provisions of the NRCS Waste Storage 313 Technical Standard.
- Report all karst-related features on the State Karst Feature Reporting Form (Appendix 5).
- Avoid manure application on areas with shallow bedrock and identified features.
- Implement buffers and setbacks.
- Require visual well inspections by property owners on a regular basis (quarterly preferred).
- Test wells for nitrate and bacteria at least annually during the runoff season or when changes are detected or suspected.
- Identify and properly abandon unused/non-compliant wells.
- Install back flow prevention devices on all new and reconditioned wells or when a major change is made to the water system.
- Educate rural homeowners on the risks of a non-compliant well and the value of correcting problems, bringing it up to code, or a drilling a new well.
- Continue to aggressively educate citizens on the threats to groundwater and the best management practices to protect the resource. This includes any or all of the following:
 - County and agency web sites.
 - Hard copies of information: pamphlets, fact sheets, reports.
 - Workshops, seminars or field days.
 - Meeting with property owners and decision makers.

Items marked with an asterisk (*) are directly from the Field Implementation subcommittee.

6: Carbonate Aquifer Protection Strategies – Enhanced Recommendations

The Task Force also discussed other actions or management practices that can be used to monitor quality and prevent groundwater contamination. The items recommended in this section will directly or indirectly affect groundwater quality and are viewed as important steps needed to ensure best use of the environment. The recommendations include improved training of farmers and professional manure haulers, better data management, and regular sharing of information among agencies and government departments.

The Task Force recognized that a great amount of information pertaining to water quality has been and continues to be collected from multiple sources throughout the region. Collation, maintenance, analysis, evaluation, and sharing of those data, however, are not uniform or consistent. Strengthening of the systems and relations involved with the collection and use of pertinent data will contribute significantly to protection of the groundwater in Northeastern Wisconsin. First, improvements will reduce the direct threats to the resource through better management and land use practices. In addition, early detection of leaks and spills as well as the selection and application of appropriate responses and solutions to those incidents will be enhanced. Recognition of common human or environmental elements in different locations will assist all stakeholders to report and deal with problems effectively and in a timely manner.

The recommendations in this section require government action at some level and/or funding to be put in place. They are viewed as critical elements of a program to bring organization and focus to groundwater protection efforts in the region.

- Mapping and designations of Karst Landscape Units. Uniform procedures need to be developed for determining these units and use across the region. As noted in Green et al., creating mapping resources that denote the potential for hidden interface features is critical to reduce potential contamination.
- Regular, scheduled training for farmers on identification and management of karst interface features.
 - Implement the module that already exists in UWEX Farmer Nutrient Management Education Curriculum (2006 edition) when farmers are trained on nutrient management.
 - Expanded farmer education for those producers not involved in the above training.
 - Implement the State Manure Task Force Recommendations on farmer training.
(<http://www.manuretaskforce.wi.gov/>)
- Training for professional manure haulers on identification and management of karst interface features.
 - UWEX and the Professional Nutrient Applicators Association must incorporate a karst module into their Level 2 training program.
 - The State Manure Task Force Recommendations included applicator training.
(<http://www.manuretaskforce.wi.gov/>)
- Create a unified, readily accessible, multi-county database of well information. This will assist agency personnel to more accurately identify areas of concern and to prioritize efforts accordingly.
 - Individual well testing data are currently in a variety of locations, including the state well database, county health departments, and LCD/SWCDs which are not easily searchable to determine trends or the extent of the problem.
 - The DNR should expand their data systems to allow for easier access to initial baseline well testing results.

—Track well test data obtain each time property is sold. (Kalamazoo County, Michigan's health department already has a prototype and posts address-specific information at: <http://www.kalcounty.com/eh/groundwater-concerns.htm#Partial>). Their version, however, only contains data sent through a public lab, and bacterial samples only when taken by agency staff.

—Initiate a local program to precisely map older (pre-1988) WDNR unique well id numbers. (Many pre-1980 well logs show only a "Rural Route 1" for a street address). Provide decals to homeowners to post in the electrical circuit breaker box that serves the well.

—Identify wells that are early indicators of problems (first in a neighborhood to show problems each spring), and consider a more rigorous testing schedule.

- Develop a mandatory program for regular inspection of wells by a professional well driller every 3-5 years. Inspection would include the well cap, casing integrity, surface slope and grade, impacts of new construction or grading, and ensure placement of Unique Well ID number.
- Locate all existing wells by GPS.
- Require installation of backflow prevention devices on existing farm water systems as allowed by state code.
- Establish programs in county health departments to offer both bacteria and nitrate testing.
- Prepare depth to bedrock maps at the town level using well logs and other available data. Provide resources to county agencies or WGNHS to complete this effort.
- Reduce water use in manure systems to create more solid manure.
- Support efforts to identify, test, and implement innovative methods to collect and process manure and their potential effects on the aquifer.
- Incorporate Karst feature and drainage tile mapping into the local requirements for ATCP 51 (Livestock Siting)
- Establish uniform ordinances and enforcement at the town level.
- The Standards and Oversight Council (SOC) should reconvene a technical committee to review the Manure Storage Standard and consider enhancing manure storage requirements in carbonate bedrock areas.
- Create a Niagara Escarpment and Carbonate Bedrock Center on the UW-Green Bay campus to serve as a clearinghouse for collection and sharing of data and information from the region and beyond.
- Create a web-based, interactive resource that landowners and waste applicators can use to determine if karst features have been found in close proximity to their existing operations or proposed new operations. Such a resource would have locally designated Karst Landscape Units, as well as data reported to the state on the Interagency Karst Reporting Form. An online mapping example from Iowa can be found at http://www.iowadnr.com/afo/maps_instruct.html, and from Minnesota at http://www.dnr.state.mn.us/waters/groundwater_section/mapping/index.html. Key to including any feature on the online system is independent field verification of each feature listed by a trained individual.

Non-Manure Wastes

We recognize that the storage, management, disposal, and application of other wastes (industrial, septage, sludge, etc) in areas with shallow carbonate bedrock also contribute to groundwater contamination. We recommend that a committee of people with expertise and knowledge of these other types of waste be formed to develop practices and restrictions for these waste products.

We also recognize that septic systems may contribute to groundwater contamination in areas with shallow carbonate bedrock and that wells may provide direct conduits for polluted runoff and wastes to enter groundwater. We recommend that separate committees with knowledgeable people be formed to develop practices and restrictions for such systems.

Needed Research

We recognize that there are concerns with the siting of certain types of animal waste storage facilities in areas of shallow carbonate bedrock. Existing technical standards and specifications may not be adequate to fully protect groundwater. We recommend that additional research be conducted on the following concerns and that additional recommendations/requirements be developed as needed to meet the following objectives.

- To better understand the characteristics and land-applied fate of manure derivatives from compost, digester and incineration facilities. These products may pose less of a groundwater quality risk than untreated manure and application may be permissible in higher vulnerability areas.
- To evaluate crop rotations and identify which crops, management practices, soils, and other conditions are most likely to contribute to acute and chronic nitrate pollution of the carbonate aquifer.
- To evaluate potential methods to conduct a bedrock surface analysis in a less invasive/destructive manner than boring or excavating at sites of both existing and proposed manure storage facilities.
- To determine the most efficient way to inventory the shallow soils in the field. Examine current and theoretical methods, including, but not limited to: hand probing, cone penetrometer+GPS, ground conductivity, etc.
- To develop greater understanding of groundwater flow in the carbonate formations that can be used to contain and remediate contamination situations.
- To assess the impacts of fall applied and incorporated manure versus waiting until spring.
- To determine if soil cracking and macropore formation can be predicted with current models and used to guide the timing of manure application.

- To investigate if weather forecasts can be used to fine-tune the timing of manure applications.
- To establish the impacts of polymers and other additives on manure product leaching.